UNIVERSITY
OF MICHIGAN
OCT 26 1953
ENGINEERING
LIBRARY

OCTOBER 1953

Battelle Technical Review

VOLUME 2, NUMBER 10

IN THIS ISSUE:

Research and Natural Gas

RESEARCH INITIATOR

BRUCE W. GONSER

Ideas, like seeds, have a twofold purpose. They bear fruit and make possible ever-expanding harvests. By giving freely of our ideas, we not only make new developments possible, but help to stimulate the thinking of others. This is the belief of Bruce W. Gonser and the key to much of his accomplishment. He has never hesitated to direct attention to fruitful new areas of research. Seeing his ideas take hold and grow has been his reward.

Since joining Battelle in 1934, Bruce has initiated studies on the development or use of such metals at titanium, molybdenum, germanium, zirconium, chromium, vanadium, thorium, rhenium, tantalum, columbium, and the rare earths. He was one of the first to institute research on the deposition and coating of metals, including hot dipping, vapor deposition, and the decomposition of metal halides. In addition, he has directed research that led to important discoveries in coated refractories, carbides, borides, and nitrides.

Bruce's career in metallurgy began after he received his degree in chemical engineering from Purdue University and his M.S. in metallurgy from the University of Utah. As a metallurgical and chemical engineer with the American Smelting and Refining Company he gained broad experience in a variety of metal operations throughout the West. After taking time out for a doctor of science degree from Harvard, Bruce returned briefly to industry. But an interview with Horace Gillett, Battelle's first director, soon drew him to the Institute.

Bruce credits Gillett's influence for his great volume of writings, which total more than four score items. His accomplishments over the years have led to many responsibilities. Currently he is a member of the Administrative Committee on Research of the American Society for Testing Materials, representative of the same organization on the Division of Engineering and Industrial Research of the National Research Council, and director of the Wire Association. For some years, he has been secretary-treasurer of the board of trustees of Tin Research Institute.

Volume 2, Number 10
October 1953

BATTELLE TECHNICAL REVIEW

Dedicated to the dissemination of knowledge. Published monthly by Battelle Memorial Institute, an endowed foundation serving mankind through science and technology

Published monthly by Battelle Memorial Institute. Please address all correspondence about articles, abstracts, subscriptions, and exchanges to: The Editor, Battelle Technical Review, Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio. Acceptance under Section 34.64 P. L. & R. authorized. Printed in the U. S. A.

contents

Research Initiator . . . . . Inside front cover

A New Area for Progress 105

Editorial

Research and Natural Gas 106

by John Farley Foster

Known reserves assure the country of adequate supplies of natural gas for several decades. While serving as a raw material for chemicals, gas will continue to be used primarily as a fuel for both industrial and domestic purposes, with growing emphasis upon the latter. Continued expansion depends to a great extent upon the development of storage facilities at pipeline terminals to meet peak demands.

Copper, Lead, and Zinc—Their Future . . . 111

by Webster Hodge

The usefulness and versatility of copper, lead, and zinc assure their expansion along with the growth of the American economy. Existing supplies of the metals will be stretched by technological improvements in mining and processing techniques, scrap recovery, and waste suppression. At the same time, adequate imports are assured from overseas deposits to satisfy domestic needs.

Notes from Battelle 113

Reports on research activities and developments of interest to science and industry.

Recent Papers and Articles by the Research Staff 115

Papers and articles prepared by members of the Battelle staff that have appeared recently in books and periodicals.

Battelle Technical Review Abstracts 511a

Abstracts of articles from more than 1000 American and foreign technical journals in a wide variety of technological fields.

Preflight Inspection . . . . . Inside back cover

A New Area For Progress

IN ALL PLANNING for the future, management should take into account the technical advances now being made in electronic mechanisms to control business procedures and production operations. These mechanisms, variously known as computers, servomechanisms, information-processing equipment, and "electronic brains", are in a high state of development. Even now they are taking over many routine control tasks of industry. Within a few years, they may produce economic and social changes comparable with those brought about in the eighteenth century by the application of steam power to industry.

In America, mass production in automatic factories is already a reality. One automobile engine plant built recently now turns out with 250 workers twice the production formerly achieved by 2500 men. This is a gain in one step of 2000 per cent in human productivity. Modern petroleum refineries are for the most part self-regulating, continuous production plants. Automatic plants for the production of consumer items are now in the planning stage.

Insurance companies, department stores, and other business organizations are also investigating the labor-saving possibilities of electronic control. In offices, these machines can be adapted to keep records, store information, and handle such tasks as billing and making up payrolls. Automatic merchandising is making rapid strides forward. Research is now being done on the development of automatic libraries for the storage, classification, and distribution of technical information. Even machines to translate one language into another have distinct possibilities.

Management will find in electronic control mechanisms ways to increase production, decrease costs, gain competitive advantages, and provide better services. The trend to machinery will relieve people of routine mental tasks and will bring unparalleled opportunities for capital employment. Labor will gradually be switched from jobs involving mental monotony to jobs that make better use of human faculties. Total production should increase tremendously, pay higher monetary and spiritual rewards, and provide more goods and more leisure time for all.

Practically all of our technology in the past has been designed to relieve mankind of physical drudgery. The principle of "feedback" in electronic circuits now enables us to build machines that can handle the functions supplied previously only by the human brain—an organ which itself works on the "feedback" principle. Mental drudgery is just as wasteful of man's higher abilities as physical drudgery, and in lessening it we have an area for progress as great or greater than any we have previously known.

While there are still unlimited opportunities for industrial progress through research on ways to save physical labor in production, management should be alert to the possibilities with these new "brain-saving" machines. Here, in one step, productivity gains are possible that may dwarf those previously made in decades of development.

Clyde Williams

President, Battelle Memorial Institute

Research and Natural Gas

by JOHN F. FOSTER

The author directs research in the fields of combustion and physical chemistry at Battelle. He also is leading investigations into new areas of inorganic chemistry. Dr. Foster is author of a number of articles and coeditor of the book, Economics of Fuel Gas from Coal. *Before joining Battelle in 1943, he was engaged in the study of surface characteristics of insulating materials for the General Electric Company. Dr. Foster is an active member of the American Gas Association and the American Chemical Society.*

ALL FUELS ARE interchangeable, and the choice of any one fuel for a particular purpose is usually determined by its cost and availability. Natural gas is used primarily as a fuel in both domestic and industrial applications. The present popularity of gas grows out of the cost advantage it enjoys in some locations compared with other domestic fuels and because it is adapted to the needs of the small consumer as well as many industrial consumers. Especially important to the domestic consumer are the advantages of convenience and cleanliness.

The need to explore for natural gas and to develop new exploration techniques is not great. Vast reserves of natural gas are already known, and the most pressing problem is that of providing economical means of transporting the fuel to market. Unfortunately, the major gas fields are distant from the great population centers. If adequate means of transportation could be provided, a tremendous expansion of gas usage would be possible.

EXPANDING NATURAL GAS SUPPLIES

Natural gas is often associated with petroleum. The steady rise of proved reserves of natural gas over a long period is largely the result of discoveries of additional petroleum fields. Up to now, these discoveries have been more than adequate to maintain gas supplies. The accompanying illustration shows both the annual production and the continual increase in reserves during the past several years.

The only certain method of exploration for either gas or petroleum is to drill a well. Considerable attention is currently being given to the development of new methods of drilling deep wells by Drilling Research, Inc. Large increases in drilling speeds, or in the service life of drill bits, with the accompanying decreases in cost, will promote more exploration and increase the likelihood of new discoveries. A number of new drilling methods have been considered, and work is in progress on the development of two vibrational methods. An experimental down-hole drilling machine is being designed to operate from power transmitted through non-vibrating drill pipe. The existence of a large-scale, coordinated attempt to reduce drilling costs is evidence of improved prospects for increasing or at least maintaining the rate of discovery of natural gas in the future.

Geophysical methods have been used extensively to detect underground formations with structures favorable to the accumulation of gas and oil. The methods are useful, but experience has shown that gas and oil are not necessarily present in favorable locations.

Geochemical methods have not been used in the United States to explore for natural gas. This is understandable, in the light of the absence of a real and immediate incentive for enlarging the natural gas reserves, and in consideration of the large amount of background data and experience that must be accumulated before geochemical measurements can be interpreted.

Recent developments of simplified forms of the mass spectrometer may provide means for extending the use of geochemical exploration in the search for natural gas and oil. This instrument could be used to identify and measure extremely small quantities of gas dissolved in ground water or adsorbed on soil particles, thus locating seepages of gas from underground reservoirs.

The problems accompanying production and gathering of natural gas are not primarily technological. For example, one of the causes of wasteful flaring of gas produced with oil is the absence of a market for the gas. Efforts to conserve flare gas are being pushed, but they embody primarily the political and legal problems of unitizing gas and oil fields, and of transferring a

part of the pipeline market from dry-gas fields to gas produced with oil.

Transportation of Natural Gas

The development of a system of pipelines for transporting natural gas over long distances has been one of the major technological advances in the effort to conserve this natural resource. Advances are still being made. The diameters of proposed pipelines and the operating pressures are increasing, with accompanying cost reductions. However, these are normal advances in technology resulting from extensions of known engineering principles, as experience is gained in pipeline design and operation. No radical improvements are foreseen in the technology of transporting natural gas by pipeline.

The transportation of liquefied natural gas at low temperature and at approximately atmospheric pressure is a possibility that has already received serious attention. One of the large oil companies at one time considered the feasibility of shipping liquefied natural gas by tanker from Venezuela to the United States. The project was never completed, because of the recent extension of pipelines to mid-Atlantic and New England areas.

Application of this method within the United States might be economically justifiable under certain conditions. The major restriction is that rail or road transportation by tank car or truck appears to be too costly. Such methods are used when costs can be justified, as is shown by the accepted practice of delivering liquid oxygen by tank car or truck. The major difference between delivery of natural gas and of oxygen would be the necessity for developing a safe method for venting the inflammable vapors from the tanks containing gas.

It is believed that liquefaction may be feasible at a location which has a supply of natural gas of 16 million cubic feet per day (MMcfd)*, for which there is no present market. It is beyond the scope of this article to identify the geographical areas having such sources of natural gas. However, if such a source of natural gas were within reasonable distance of tidewater, a liquefaction plant might be used. A reasonable distance would probably be less than 100 miles, and preferably less than 50 miles. Over such a distance, a pipeline could conceivably be justified to transport gas by field pressure to the liquefaction plant, thus eliminating the cost of compressor stations. The cost of delivering gas to the plant would vary, under these conditions, from one to perhaps $.03 per Mcf.

Total delivered cost of 16 MMcfd of liquefied gas delivered by ocean tanker 1500 miles from the liquefaction plant is estimated as follows:

Unmarketable gas at well	$0.06 per Mcf
Gathering	0.02 per Mcf
Liquefaction	0.20 per Mcf
Transportation	0.10 per Mcf

The estimate of $0.38 per Mcf is believed to be conservative; with lower, but still reasonable, estimates for some of the individual items, the total cost might be as much as 20 per cent less.

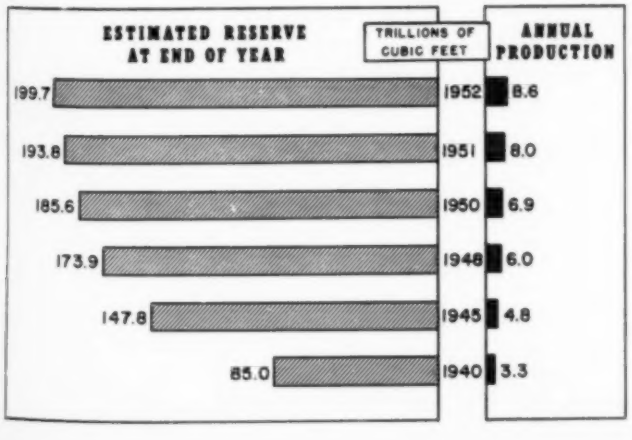
By way of comparison, costs would be about $0.28 to $0.35 per Mcf for gas delivered by 24-inch pipeline to markets 1500 miles distant at load factors of 70 to 90 per cent.

Such comparisons are always open to some question because the estimates cannot be made very precisely without selecting a specific plant site or pipeline route and following up with extensive engineering studies. Nevertheless, the comparison does indicate that liquefaction, combined with low-cost transportation by ocean tanker or tank barge, may be able to supplement the pipelines, in spite of a possible higher delivered cost for the gas. There would be the additional advantage that the terminal point would not be fixed, but delivery could be made at any point where unloading and storage facilities were provided. Thus, low-temperature liquefaction may be in the future an additional, technologically sound procedure for conserving natural gas.

Storage Problems

There is a large economic advantage in the ability to store natural gas near the point of use during periods of slack demand and to recover it quickly for distribution in times of peak demand. This is true because the terminal cost of gas from pipelines is made up predominantly of fixed charges on the pipeline invest-

U.S. Natural Gas Reserves and Production



* M means 1000, MM means 1,000,000.

ment. Thus, the pipeline must operate at or near capacity if unit costs are to be kept low. Much gas has been sold during the summer months at low prices, in order to use the pipeline to capacity. For example, as calculated from Federal Power Commission Report 53-6B, natural gas supplied 28 percent of the fuel requirements of electric utilities in June, 1953. This low-grade use will be reduced and natural gas will be reserved for other purposes at a higher selling price, as soon as adequate storage facilities can be provided.

Low-cost methods of storage are actively being sought. Underground storage of pipeline gas in exhausted gas fields near the terminal has been used for some time. A recent development is the use of suitable porous strata which have never contained gas. Fabricated storage facilities of like capacity would be impractical, because low-pressure multiple-lift holders cost approximately $100 per Mcf. Peoples Gas Light and Coke Company of Chicago is developing storage facilities in a porous sandstone formation near Chicago, which will have a capacity of 80 billion cubic feet of gas. It is estimated that six additional pipelines would be required to provide the same effective delivery from Texas to Chicago. These would cost 35 to 40 times as much as the $30 million investment planned in this storage development. The storage facility represents a cost of about $2.60 per Mcf of capacity.

Other methods of storing natural gas are in the development stage. Storage as a liquid results in a volume reduction of about 600 to 1. This was tried in Cleveland in 1941, and the plant operated successfully until 1943. Although failure of one of the storage tanks at the plant caused a disastrous fire, there is no reason why the method should not be successful, if backed by proper engineering design and accompanied by proper safety precautions. Storage-tank facilities for liquefied gas constructed of steel cost about $7 per Mcf of capacity.

There appears to be a good prospect that investment costs for storage facilities for liquefied natural gas may be reduced drastically by research.

If a suitable material can be developed for lining an insulated excavation, then much of the cost and difficulty of constructing steel tanks will be avoided. Such a material would have to be impervious to liquid methane, strong or flexible at low temperatures, and easily handled for application to its supporting structure at ordinary temperatures. It is possible that either metal foil or a special plastic formulation could serve.

Adsorption storage is also being developed. Liquefied natural gas is charged to a container filled with a proprietary adsorbent prepared from fuller's earth. The advantage of this method is that the liquefied gas is released slowly if the container fails. The volumetric reduction by this method is about 300 to 1, or about half as great as with straight liquefaction. Investment costs would probably be higher than for liquid storage.

Another method that is already in use is high-pressure storage at ambient temperature in underground steel pipes of large diameter. Because of the supercompressibility of natural gas, the volume reduction is about 200 to 1 at pressures somewhat above 2000 psi. Investment costs spread over a wide range, but may be of the order of $40 per Mcf.

Fuel Uses of Natural Gas

The demand for gas for household use is far from satisfied at the present time. Since natural gas is particularly adapted to the needs of the small consumer, the domestic market is likely to increase tremendously during the next 25 years. It is conceivable that it will more than double in that period. It is also probable that a part of this rapid rise will be balanced by a slower rate of increase in other uses, because gas will be supplied to this premium market in preference to others. Thus, the percentage of total production devoted to domestic use will move upward from the present figure of about 20 per cent.

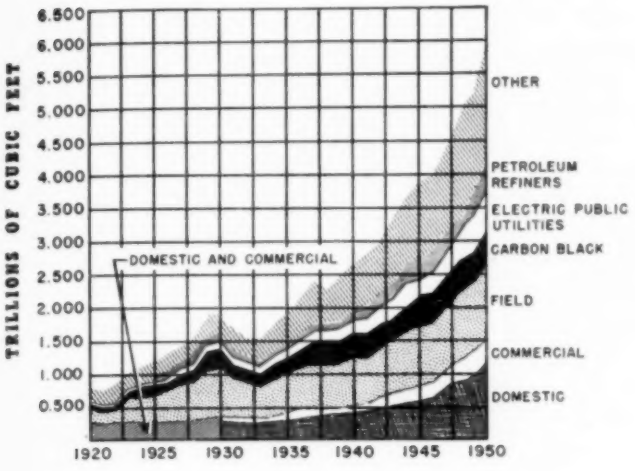
No technological developments are foreseen that will have a significant effect on the market in the highly industrialized areas served by pipelines. Higher prices for gas at pipeline terminals may retard the rate of growth of the market in these areas by causing substitution of coal, or by encouraging movement of industry to the source of natural gas. An example of the latter is the new Alcoa plant on the Gulf Coast which uses 30 MMcfd of natural gas direct from the wells in generating 2¾ million kw.-hr. for aluminum production.

Uses for Chemicals

Chemical uses for natural gas are relatively new and unimportant when compared to other uses. If the so-called natural gas liquids are included, then the chemical uses are significant. However, no radical dislocations of the projected growth trend of the chemical use of natural gas liquids are foreseen.

The need is recognized for a method of using isolated gas supplies at the source, with low investment and operating costs. If research can devise a process to compete in the chemical market with products for which there is a steady demand, the problem of using isolated gas supplies will be less pressing. A really novel process will no doubt be necessary to meet the requirements.

Pattern of Natural Gas Consumption



Natural gas is the most important basic material for the production of ammonia. Approximately 65 per cent is now being made from this source, and additional plants, using the same process, are being constructed. Though it is extremely important to the ammonia industry, the amount of natural gas consumed by the industry is a very small fraction of the total annual production.

One of the largest individual uses of natural gas is for the production of carbon black. This has been a residual use for natural gas that is effectively without another market. The trend is already in the direction of a reduction of this use.

The least efficient process, that of channel black production, recovers as black only about 3 to 5 per cent of the carbon in the gas. Channel black, with its minimum particle size, was originally regarded as a superior product for rubber compounding. At the present time furnace black, produced with carbon recoveries of up to 30 per cent, is capturing a larger proportion of the market. The furnace blacks can now be produced in a wide variety of grades of controlled quality, and they will probably in time take over a preponderant part of the market. Specialty uses for channel black, such as for ink pigments, may continue but these will require an unimportant part of the natural gas supply.

Another trend toward the replacement of natural gas by petroleum liquids as raw materials for black production is already evident. A variety of liquid products has been used, including certain types of crude oil. Residual oils can also be used. The price and availability of the petroleum liquids, together with the efficiency of utilization and the properties of the product, will determine the extent of their substitution for natural gas.

If both natural gas and petroleum rise in price sufficiently, it is almost certain that other raw materials can provide substitutes for carbon black. The development of two major classes of substitutes, finely divided silica and processed lignin, is proceeding. It is entirely possible, too, that these eventually may be able to compete at the present price. It is not now a question of economics, but of the necessity for further technological improvement of these materials.

Research aimed at their improvement is extremely active. However, the use of substitutes for carbon black in significant quantities is not likely to come rapidly because of the understandable and justifiable reluctance of the rubber industry to make radical changes in compounding procedures. This reluctance stems from the inability of laboratory-scale tests to predict precisely the results of large-scale changes. Mistakes on such a scale are serious in a highly competitive industry.

One German process for producing finely divided silica claims a power consumption of only 2 kw.-hr. per pound of product. The product is reported to have an average particle size of about 40A. The manufacturing procedure is relatively simple, and costs should be in the same range as carbon black.

No useful cost estimates can be made on lignin-derived substitutes. However, lignin is a waste product available in large quantities from paper manufacture, and the process is reported to be comparatively simple.

Other Uses

The production of liquid fuels from natural gas by processes now known is not likely to take over a significant part of the natural gas supply within the next 25 years. In the first place, even before a plant can be built, natural gas reserves must be assured for a period of at least 20 years. Not many areas remain in which such large reserves of gas are available. Moreover, the production of liquid fuels is wasteful of energy since the over-all thermal efficiency of conversion may be less than 50 per cent.

Roughly one-fifth of natural gas production is used in the field. Rising field prices will exert pressure for substitution of other forms of energy. Texas, for example, has unexploited and largely unexplored reserves of lignite that might become useful for electric power generation. The lignite fields are reasonably close to many gas fields. As evidence of the practicality of this idea, it can be pointed out that a large aluminum plant is being built in the lignite area. It will employ processed lignite as fuel for electric power. If by-product credits are adequate, costs should be competitive with gas-using power plants based at the gas fields.

In the future, natural gas will continue to be important primarily as a fuel. Its continued expansion, both in industrial and domestic use, will depend largely on the solution of transportation and storage problems. Storage is the real bottleneck. Adequate supplies in storage are a necessity for meeting the peak demands that now set a limit to the amount of gas that can be distributed. This problem, which is likely to raise the costs of natural gas, may discourage wider industrial use. Because of its convenience, however, demands by domestic consumers will continue to grow as long as the cost of gas remains within reason.

QUESTIONS TO THE ACADEMIC SCIENTIST

The industrial research man is faced with so many unknowns that block his progress that he may at times question the free and untrammeled pure researcher in some of his choice of projects. Perhaps this is a perennial dilemma. While the value of academic freedom is recognized, many problems of a basic nature that are simply crying for answers must be faced. The answers can only come from researchers in pure science.

If the magnitude of the job ahead is taken into account, it may be wise for the university men who lead graduates into thesis work and the research administrators in pure science to ask two questions:

"Is this project truly a work that has significance, or is it simply a challenge to the ingenuity of my specialty? How does this inquiry rate in the value of its findings when measured against the pressing need for basic information in the field of applied science?"

Carroll A. Hochwalt
Monsanto Chemical Company

Copper, Lead and Zinc--Their Future

by WEBSTER HODGE

The author serves as a consulting metallurgist in research on the production and processing of nonferrous metals at Battelle. Before joining the Institute in 1945, he served as a testing engineer with the Braden Copper Company, Rancagua, Chile, as a metallurgist with the United States Refining Company, and as research engineer with the Amco Magnesium Corporation.

COPPER, LEAD, AND ZINC, like all other commercial metals, have shared in the country's rapid industrial growth. Current consumption of each of these metals has about doubled since 1920. The usefulness and versatility of the materials is so well entrenched in our daily lives that continued expansion in their consumption is assured as long as the American economy expands. By 1975, according to one estimate, the United States will need 45 per cent more lead and 38 per cent more zinc than in 1950.

Although temporary shortages may occur from price difficulties or a national emergency, copper, lead, and zinc producers will meet such increased demands. As in the past, they will do so by making the most of technological advances that enable them to produce the highest quality in their products at the lowest cost. Existing supplies of the metals will be stretched by more efficient mining and processing techniques and by continued emphasis on recovery of scrap and waste suppression. Fundamental to future achievement, of course, is an economic environment that encourages the working of lower grade ores and exploration for new deposits.

APPLICATIONS OF THE METALS

Expanding future needs for copper, lead, and zinc are linked with many of the country's most important industries that grow as the American economy grows. Copper and copper alloys are vital to electric-power generation and distribution, telephone and telegraph systems, automobiles, radio and television, railroads, ships, ammunition, and building construction. The biggest use is in the making of electrical equipment including motors, generators, switchboards, transmission lines, and transformers, as well as wiring of all kinds. Large quantities are also used in many other products such as radiators for automobiles, propellers for ships, cartridge cases and rotating bands for artillery shells, bearings for locomotives, and hardware and plumbing fixtures for the building industry.

The automotive, aviation, telephone, electric power, and chemical industries depend heavily on lead for doing key jobs. About 31 per cent of the lead consumed in 1952 went into the making of storage battery plates and 13 per cent into cable coverings for telephone and electric-power lines. As a unique ingredient for antiknock compounds in high-test gasolines, the metal has become increasingly important. Red lead in marine paints is still preferred to other pigments for fighting sea-water corrosion.

Zinc is the most widely used and cheapest metallic coating for protecting iron and steel against atmospheric corrosion. The galvanizing business accounts for nearly half of the country's total consumption of zinc. Zinc-base alloys are used in the die-casting of many parts for automobiles, appliances, and utensils. Rolled zinc is used in the making of dry-cell batteries and engraving plates. Alloyed with copper, the metal has valuable applications in brass products.

The nature and uses of copper, lead, and zinc affect the percentage of each metal that can be recovered from scrap by the usual processing methods. Because of the character of its applications, large proportions of copper can be recovered without difficulty. Lead, when used in the manufacture of paints and as an antiknock component of gasoline, cannot be reclaimed; in its other uses, however, it is largely recoverable. Zinc has the lowest rate of recoverability of the three metals. Zinc used in galvanizing is lost. Moreover, when alloyed with heavier metals, as in brass making, little of it can be recovered. Because of these losses, zinc is more dependent than copper and lead upon continued mining and improved technologies for adequate supplies.

The alertness of the copper industry in applying technological improvements to their mining and pro-

cessing operations is typical of the progressiveness of the nonferrous metal industries. Better drilling, blasting, and hauling techniques have been a major factor in improving mining yields. Available statistics show that ore tonnage output per man-hour more than doubled between 1935 and 1945. Lower grade copper deposits have been made an important source of supply. These deposits include those existing in worked-out mines, waste dumps, and tailings. The country is now obtaining most of its copper from ores that contain about one per cent of the metal, as compared to 5 per cent in 1890. In recent years, the ingenuity of mining engineers in making the mining of low-grade ores profitable has brought into production huge deposits at Bisbee, Arizona and Butte, Montana. Such operations no doubt will continue as long as the price of copper remains sufficiently high to render them worth while.

Foreign Sources

Recognizing the key role of imports in the country's total supply picture, copper, lead, and zinc producers have always sought to develop maximum output from overseas deposits. In 1950, about one-third of our consumption of zinc, one-half of the lead, and one-fourth of the copper came from abroad. Outstanding among recent overseas efforts are those being made at the American-owned Chuquicamata mine in Chile, probably the largest single source of copper in the world. Here, new processing equipment is being installed that will greatly expand production from previously untapped reserves. Peru and Northern Rhodesia are being studied for expansion in their copper production potentials.

The use of alternative materials, such as aluminum, magnesium, iron, steel, and plastics, will gradually take over certain jobs previously done by copper, lead, and zinc. The extent of such replacement, generally, will be governed by the performance, cost, and supply of the alternative material in a given job, as compared to the original material used.

Metal producers, however, will take in stride any replacement of copper, lead, or zinc by alternative materials. The country will still need greater quantities of copper, lead, and zinc for their most essential uses. In the electrical industry, for example, where copper has its greatest use, expanding needs within the next 75 to 100 years, if not before, might require all available supplies of this metal. Copper, lead, and zinc, furthermore, have such excellent properties that new uses will always be found to compensate for losses in old applications. In the last 30 years, lead as an antiknock compound in high-test gasolines has taken on increasing importance. Recent studies at Battelle verify that copper is a useful constituent in fertilizer and in antifouling paints for ship bottoms.

The proven resourcefulness of copper, lead, and zinc producers in keeping pace with the expanding needs of the American economy and in developing new markets for their products assures a healthy long-range outlook for the metals.

MAN AS A METER

As a comparison instrument, man exhibits sensitivities from excellent to very poor, depending on the quantity being measured. In judging whether one mass exceeds another, he cannot do better than 1.0 per cent at best and that only over a very limited range. He can hardly be considered, therefore, as a competitor to the analytic balance or to the microbalance. On the other hand, no device yet built can do better than the human eye in judging the match of two colors. In the measurement of loudness, the human ear is little better than a qualitative device; in detecting differences of pitch it can compete with quite complicated apparatus. Detection of a beat note between frequencies differing by 0.005 per second has been reported.

Walter C. Michels and Harry Nelson in *Physics Today*

Notes From Battelle

TANNAGE PROBLEMS IN GRAVURE

The preparation of a gravure cylinder as a printing plate requires several distinct operations. Research on these operations at Battelle has included study of the chemistry of sensitization, exposure, and development of carbon tissue.

Carbon tissue, or pigment paper, is composed of a gelatin emulsion and a coloring material attached to a paper backing. After the tissue is sensitized to light, it is exposed to fix the desired image as a tanning or hardening of the emulsion. If the tanning can be stopped at this point, an excellent image is obtained for transfer to the cylinder. However, a number of problems may arise because of the continuance of tanning caused by uncontrolled temperature rise and a tendency to establish an equilibrium.

James M. Dugan of Battelle, reports that careful investigations of the reactions involved in the treatment of tissues have resulted in procedures that will minimize the tendency toward tanning after the tissue has been sensitized.

The so-called "dark reaction" that takes place if the system is warm can be practically stopped by refrigerating the sensitized tissue before exposure. Another problem is the "continuing action" or progressive shift to equilibrium conditions between the hardened and unhardened portions of the exposed tissue. Impurities in the sensitizing bath, higher humidity, and higher temperatures tend to increase these actions. Research has shown that "continuing action" is less pronounced when exposures are of low intensity and long duration. Refrigeration and a shorter period between laydown and development of the tissue also aid in controlling such tanning.

ELECTRIC VS. OPEN-HEARTH FURNACES

Through World War II, electric furnaces were used primarily to make special alloy steels. The end of the war reduced demands for such steels, and makers experimented with the manufacture of low-carbon steels in their electric furnaces. At the same time, such developments as the swing roof, high rates of energy input, and increase in furnace size were introduced. The resulting economies brought electric-furnace costs close to the level of the open-hearth process.

A study of the subject was recently completed at Battelle for an association of 14 electric utility companies and Bituminous Coal Research, Inc. According to S. L. Case, C. E. Sims, D. D. Moore, and R. J. Lund, authors of the study report, capital cost for electric-furnace installations is only 60 per cent of that for equivalent open-hearth furnaces. This permits electric furnaces to show a greater annual return on invested capital.

The Battelle study was based on cost-comparison estimates of 250,000-, 500,000-, and 1,000,000-ton plants. In the cold-melt steelmaking process, electric furnaces show savings in costs up to $3.20 per ton. For the 50 per cent hot metal-50 per cent scrap metal process, annual return on invested capital with the electric furnace is equal to or greater than the open-hearth. In hot-metal practice, however, estimates of net production costs were higher for electric furnaces.

The report noted the outstanding advantages of the electric furnaces. They are more flexible and can be withdrawn from production without damage. The electric furnace can operate all but 15 days a year as against average annual open-hearth closedowns for 30 days. The former also has a 2 per cent greater yield for the same amount of metal and at the same time, gives greater control of sulfur in production. Finally, because of better temperature control, the electric furnace saves time in steel production.

On the basis of the report, Bituminous Coal Research, Inc., estimates that the use of electric furnaces could increase the national demand for electricity by 12 per cent and increase the market for coal about 25,000,000 tons per year. These estimates assume a total replacement of the existing 950 open-hearth furnaces, fired primarily by oil, with 760 electric furnaces utilizing power generated from coal.

RE-EVALUATING METALS

Metals manufacturers are making every effort to keep pace with the increasingly exacting metals needs of industry. One result of this effort is the critical evaluation of the older metals, particularly in their pure form. In recent years, metallurgists have found that tiny amounts of impurities may control, or even obscure, the true properties of pure metals.

It is a metallurgical axiom that pure metals can be expected to show maximum electrical conductivity,

magnetic permeability, corrosion resistance, and ductility, but that they tend to exhibit a minimum in yield and tensile strength. The addition of contaminating elements, on the other hand, increases the strength of metals but usually at the expense of other properties.

D. J. Maykuth and Bruce Gonser, Battelle metallurgists, point out that most of the metallic elements have been isolated in a pure enough state to make their principal properties known. Yet metallurgists do not know the full effects of trace impurities on the properties. Careful investigations of the effects may well lead to further improvements in the qualities of commercial metals and their alloys. Such studies may also aid in future alloy design by allowing metallurgists to choose metals to fit the performances required.

MILLING PURE CERAMIC BODIES

Increasing engineering demands for pure ceramic materials are difficult to satisfy. Previous practice involved milling in iron or steel equipment, followed by laborious acid leaching and washing to remove contaminating materials. Improved methods have been developed at Battelle, however, which promise to make the milling of pure materials easier.

Writing in the *American Ceramic Society Bulletin*, Zane Schofield, ceramic consultant at Battelle, outlined the procedures. He pointed out that contamination can be kept to a minimum by using materials for mill lining and balls which (1) are of the same composition as the body being milled, (2) will oxidize to the composition of the body when fired, and (3) will burn out during firing. Thus cast beryllium may be used for milling fused beryllia, magnesia lumps in a rubber mill will process fused magnesia, and zirconium balls are effective with fused zirconia and zirconium carbide.

STRUCTURE OF A VIRUS

One of the important areas of research for biologists is in the shadowy region between living tissues and complex chemical. Some years ago, a scientist was able to crystallize viruses. Since that time, biologists have been unable to agree that a virus is living matter.

An investigation carried on by Nelson Newton, Foster Ewing, and Carl Melton, of Battelle, may help to throw light on this problem. They attempted to stain the ribonucleic acid fraction of tobacco mosaic virus. The Battelle scientists used an electron-staining technique that L. H. Bretschneider developed for use with a closely related substance, desoxyribonucleic acid, found in the nuclei of living cells.

When viewed under the electron microscope, the stained virus appeared as an enlarged rod-shaped structure with dark, inner thread-like components running through its length. There appears to be good reason to believe that the thread-like forms are the ribonucleic acid fraction of the virus. If true, the structure of the virus may be more clearly understood than formerly. This, in turn, bears on the problem of determining the nature of viruses, since such a differentiation in structure is generally associated with some of the more primitive forms of living matter.

CHEMICAL CONSULTANT

Dr. Edward L. Kropa, formerly vice-president and chemical director of The Borden Company's chemical division, has been named chief chemical consultant on the Battelle staff. In his new position, Dr. Kropa will serve as an adviser to Battelle's varied chemical research groups.

While associated with Borden, Dr. Kropa was interested in research and development in the fields of casein, wood and metal adhesives, foundry products, molding compounds, and industrial resins. Prior to his association with The Borden Company, he had served as chemist to the head of the resins and plastics section of the research division of the American Cyanamid Company. In that position he conducted studies in resins, synthetic rubber, synthetic fibers, and plastics, which resulted in nearly 100 United States patents.

Dr. Kropa has served as consultant to the National Research Council's Advisory Committee on Quartermaster Problems. Earlier, he was adjunct professor of chemical engineering at New York University's College of Engineering in New York City.

CONSULTANT ON NONFUEL USES OF COAL

The development of nonfuel uses of coal, including research on the derivation of chemicals from coal, is receiving increased attention at Battelle. As a result, Howard R. Batchelder has joined the Institute staff to coordinate research in that field.

Previously, Batchelder had been in charge of gasification planning at the Fuels Demonstration Plant of the United States Bureau of Mines in Louisiana, Missouri. While there, he also served as consultant on gasification to the Chief of the Division of Fuels Technology of the Bureau's Region VIII. Earlier in his career, Batchelder had served as Technical Director of the Institute of Gas Technology in Chicago.

The new consultant is author or coauthor of more than a score of papers on coal gasification and synthetic fuels. He is also holder of 12 United States patents on processes for recovering and refining products from high-temperature pyrolysis of petroleum.

RECENT PAPERS AND ARTICLES BY THE RESEARCH STAFF*

Effect of Shape and Material on the Thermal Rupture of Ceramics. E. M. Baroody, W. H. Duckworth, E. M. Simons, and H. Z. Schofield. Battelle Memorial Institute for the Atomic Energy Commission, AECD-3486, May 22, 1953. (Available from Office of Technical Services, Department of Commerce, Washington 25, D. C.)

Materials for High-Temperature Service. Howard C. Cross *Industrial Heating*, August, 1953.

Ceramics in the American Economy. Betty Deem and John D. Sullivan. *American Ceramic Society, Bulletin*, August, 1953.

Metals, Mining, and Meditation. Bruce W. Gonser. *Mines Magazine*, May, 1953.

Corrosion of Mercury-Boiler Tubes During Combustion of a Heavy Residual Oil. A. M. Hall, D. Douglass, and J. H. Jackson. *American Society of Mechanical Engineers, Transactions*, August, 1953.

Industrial Research as a Tool of Industry. S. L. Hoyt. *Metal Progress*, July, 1953.

Resistance of Cast Fe-Cr-Ni Alloys to Corrosion in Oxidizing and Reducing Flue-Gas Atmosphere. J. H. Jackson, C. J. Slunder, O. E. Harder, and J. T. Gow. *American Society of Mechanical Engineers, Transactions*, August, 1953.

The Creep of Single Crystals of Aluminum. R. D. Johnson, F. R. Shober, and A. D. Schwope. National Advisory Committee for Aeronautics, Washington, D. C., Technical Note 2945, May, 1953.

Understanding Melt Quality. J. G. Kura. *American Foundryman*, August, 1953.

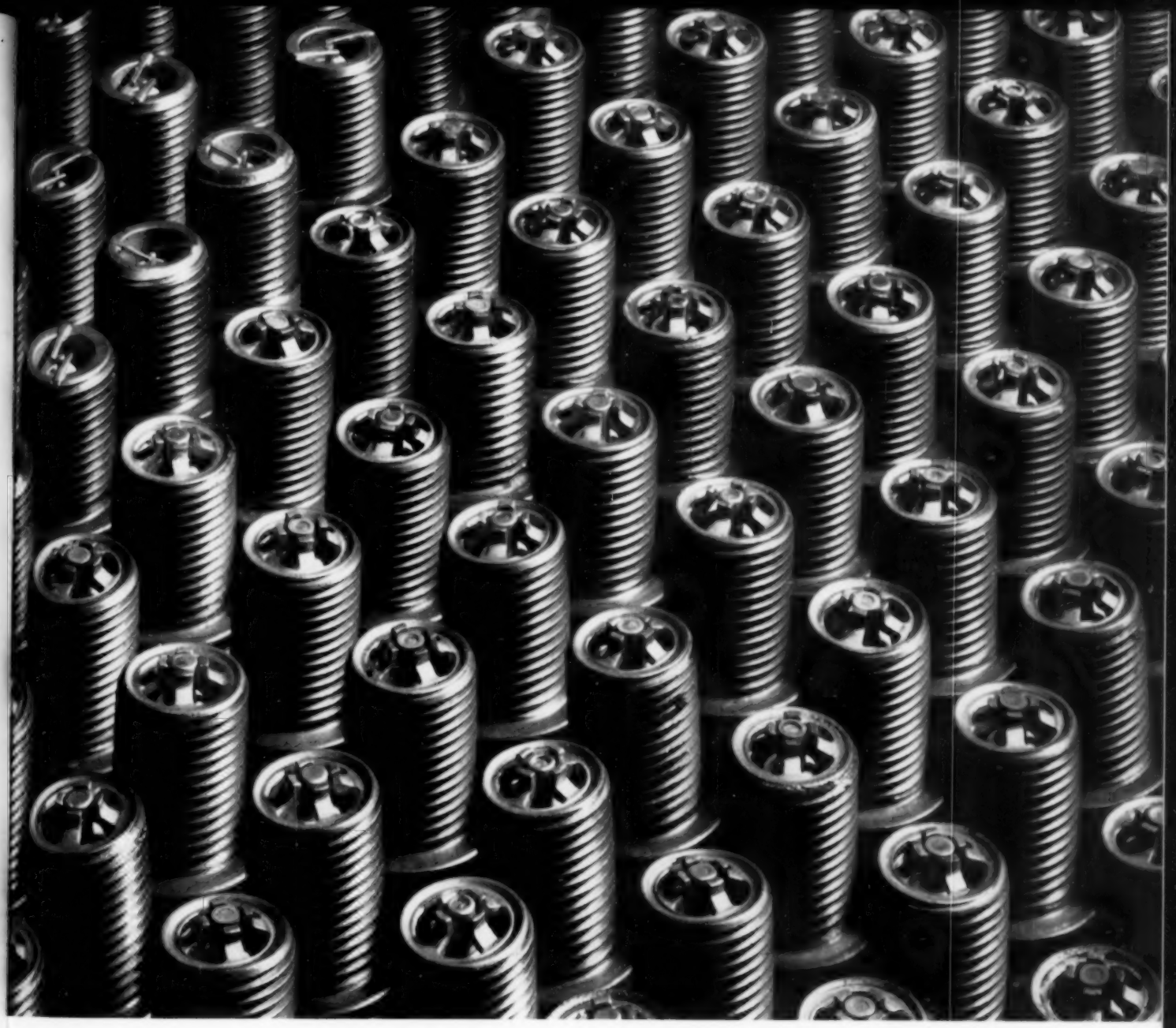
The Hissing Arc and Radio-Frequency Self-Generated Oscillations in the D-C Carbon Arc. B. H. List and T. B. Jones. *Electrical Engineering*, August, 1953.

Laboratory Investigation of Superheater-Tubing Materials in Contact with Synthetic Combustion Atmospheres at 1350 F. C. J. Slunder, A. M. Hall, and J. H. Jackson. *American Society of Mechanical Engineers, Transactions*, August, 1953.

*In most cases, reprints will be available from the Battelle Publications Office upon request.

A Word About Battelle Technical Review Abstracts

The abstracts that appear in the following pages are prepared from approximately 1000 American and foreign technical journals, as well as from books and other literature received in the Battelle Library. Prepared by a professional staff trained in various technological fields, the abstracts are selected for their usefulness to the Battelle research staff. They are now being made available to technologists and scientists in industry and research in all parts of the world, through the pages of the *Battelle Technical Review*.



PREFLIGHT INSPECTION

These spark plugs are ready for inspection and flight evaluation by the Air Force. They are reconditioned plugs that have been cleaned by a new process developed at Battelle under Air Force sponsorship. The process involves blasting a high-velocity spray of hot caustic soda into the firing head of the spark plugs. The spray is more effective than abrasive blasting in removing lead compounds resulting from the tetraethyllead in the gasoline. At the same time, erosion of the electrodes by the spray is negligible.

BATTELLE INSTITUTE was founded by the will of Gordon Battelle as a memorial to the Battelle family. The Battelles were among the first settlers of Ohio and were prominent in the development of the state's iron and steel industry.

Gordon Battelle, last of the family line, was impressed with the benefits to be derived from industrial research and left his estate for the building and endowment of an Institute "for the purpose of education . . . the encouragement of research . . . and the making of discoveries and inventions for industry." The Institute began operations in 1929.

As established, Battelle provides, on a not-for-profit basis, the physical plant, equipment, and personnel for conducting research. The great bulk of it is applied research conducted for industry and government.

In keeping with its educational function, the Institute also conducts fundamental or basic research. The results of much of this research are published for the general encouragement of science and industry, and to benefit the public welfare.

Fields of research at Battelle include agriculture and practically all the industrial and engineering sciences.

VOLUME 2, NUMBER 11 NOVEMBER 1953